

## CLAIMS

What is claimed is:

- 5           1.       A method for permanently physically and electrically attaching a first electrical component of an RFID device having a first electrically conductive contact to a second electrical component of the RFID device having a second electrically conductive contact wherein an electrical connection is formed between the first and second electrically conductive contacts, the method comprising:
- 10           attaching at least one electrically conductive hard particle to at least one of the first and second electrically conductive contacts,
- wherein the at least one electrically conductive hard particle has a hardness at least as great as that of at least one of the first and second electrically conductive contacts;
- disposing a non-conductive adhesive between the first and second electrically
- 15           conductive contacts;
- placing the first and second electrically conductive contacts in alignment with one another;
- applying pressure to hold the first and second electrically conductive contacts together; and
- 20           curing the non-conductive adhesive,
- thereby creating a permanent electrical connection between the first and second electrically conductive contacts, and
- permanently physically attaching the first electrical component to the second electrical component.
- 25           2.       The method of claim 1, wherein the pressure applied is sufficient enough for the at least one electrically conductive hard particle to pierce a surface of at least one of the first and second electrically conductive contacts.
- 30           3.       The method of claim 1, wherein the step of disposing the nonconductive adhesive further comprises disposing the non-conductive adhesive between the first electrical component and the second electrical component.

4. The method of claim 1 or 3 further comprising applying pressure to the first and second electrical components during at least a portion of the step of curing.

5. The method of claim 1 further comprising depositing an electrically  
5 conductive metal layer on the at least one electrically conductive hard particle.

6. The method of claim 5, wherein the step of attaching the at least one electrically conductive hard particle and the step of depositing the electrically conductive metal layer occur simultaneously.

10 7. The method of claim 1, wherein the first electrical component is a chip and the second electrical component is a chip carrier, and  
wherein the step of attaching further comprises attaching the at least one electrically conductive hard particle to a bond pad on the chip.

15 8. The method of claim 1, wherein the first electrical component is a chip and the second electrical component is a chip carrier, and  
wherein the step of attaching further comprises attaching the at least one electrically conductive hard particle to a contact land on the chip carrier.

20 9. The method of claim 1, wherein the first electrical component is a module and the second electrical component is an electrically conductive area, and  
wherein the step of attaching further comprises attaching the at least one electrically conductive hard particle to a contact land on the module.

25 10. The method of claim 1, wherein the first electrical component is a module and the second electrical component is an electrically conductive area, and  
wherein the step of attaching further comprises attaching the at least one electrically conductive hard particle to a contact area on the electrically conductive area.

30 11. The method of claim 1, wherein the first electrical component is a chip and the second electrical component is an electrically conductive area, and  
wherein the step of attaching further comprises attaching the at least one electrically conductive hard particle to a bond pad on the chip.

12. The method of claim 1, wherein the first electrical component is a chip and the second electrical component is an electrically conductive area, and

wherein the step of attaching further comprises attaching the at least one electrically  
5 conductive hard particle to a contact area on the electrically conductive area.

13. The method of claim 9, 10, 11, or 12, wherein the electrically conductive area comprises a conductive path.

10 14. The method of claim 9, 10, 11, or 12, wherein the electrically conductive area comprises an antenna.

15 15. The method of claim 9, 10, 11, or 12, wherein the electrically conductive area comprises a conductive material comprising at least one of the following: copper, aluminum, gold, metal foils, conductive inks, conductive pastes, and graphite.

20 16. The method of claim 1, wherein the at least one electrically conductive hard particle is a metal particle comprising at least one of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum, palladium, lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium, rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of these metals.

25 17. The method of claim 1, wherein the at least one electrically conductive hard particle comprises a non-electrically-conductive particle core surrounded by a metal layer, and wherein the non-conductive particle core comprises at least one of the following: diamond, garnet, ceramic, oxides, silicides, silicates, carbides, carbonates, borides, boron fibers, and nitrides.

30 18. The method of claim 1 or 17, wherein the step of attaching the at least one electrically conductive hard particle comprises an electrolytic metal-particle co-deposition process.

19. The method of claim 1 or 17, wherein the step of attaching the at least one electrically conductive hard particle comprises an electroless metal-particle co-deposition process.

20. The method of claim 17, wherein the metal layer comprises a nickel layer and wherein the non-electrically conductive particle core comprises diamond.

21. The method of claim 17, wherein the metal layer comprises at least one of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum, palladium, lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium, rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of these metals.

22. The method of claim 1, wherein the at least one electrically conductive hard particle comprises a plurality of electrically conductive hard particles.

23. The method of claim 1, wherein the RFID device is a smart card.

24. The method of claim 1, wherein the RFID device is a smart inlay.

25. The method of claim 24, wherein the smart inlay is comprised within at least one of a smart label and a smart paper.

26. An RFID device comprising:  
a first electrical component having  
a first electrically conductive contact;  
a second electrical component having  
a second electrically conductive contact;  
wherein the first and second electrically conductive contacts are in alignment  
with one another  
at least one electrically conductive hard particle attached to at least one of the first and second electrically conductive contacts,  
wherein the at least one electrically conductive hard particle has a hardness at least as great as that of at least one of the first and second electrically conductive contacts;

a non-conductive adhesive disposed between the first and second electrically conductive contacts;

wherein the first and second electrically conductive contacts are held together by the non-conductive adhesive once the adhesive cures;

5 wherein a permanent electrical connection is formed between the first and second electrically conductive contacts; and

wherein a permanent physical attachment is formed between the first electrical component and the second electrical component.

10 27. The RFID device of claim 26, wherein the at least one electrically conductive hard particle pierces a surface of at least one of the first and second electrically conductive contacts.

15 28. The RFID device of claim 26, wherein the nonconductive adhesive is further disposed between the first electrical component to the second electrical component.

29. The RFID device of claim 26 further comprising an electrically conductive metal layer deposited on the at least one electrically conductive hard particle.

20 30. The RFID device of claim 26, wherein the first component is a chip and the second component is a chip carrier, and

wherein the at least one electrically conductive hard particle is attached to a bond pad on the chip.

25 31. The RFID device of claim 26, wherein the first component is a chip and the second component is a chip carrier, and

wherein the at least one electrically conductive hard particle is attached to a contact land on the chip carrier.

30 32. The RFID device of claim 26, wherein the first component is a module and the second component is an electrically conductive area, and

wherein the at least one electrically conductive hard particle is attached to a contact land on the module.

33. The RFID device of claim 26, wherein the first component is a module and the second component is an electrically conductive area, and

wherein the at least one electrically conductive hard particle is attached to a contact area on the electrically conductive area.

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34. The RFID device of claim 26, wherein the first component is a chip and the second component is an electrically conductive area, and

wherein the at least one electrically conductive hard particle is attached to a bond pad on the chip.

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35. The RFID device of claim 26, wherein the first component is a chip and the second component is an electrically conductive area, and

wherein the at least one electrically conductive hard particle is attached to a contact area on the electrically conductive area.

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36. The RFID device of claim 32, 33, 34 or 35, wherein the electrically conductive area comprises a conductive path.

37. The RFID device of claim 32, 33, 34 or 35, wherein the electrically conductive area comprises an antenna.

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38. The RFID device of claim 32, 33, 34 or 35, wherein the electrically conductive area comprises a conductive material comprising at least one of the following: copper, aluminum, gold, metal foils, conductive inks, conductive pastes, and graphite.

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39. The RFID device of claim 26, wherein the at least one electrically conductive hard particle is a metal particle comprising at least one of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum, palladium, lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium, rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of these metals.

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40. The RFID device of claim 26, wherein the at least one electrically conductive hard particle comprises a non-electrically-conductive particle core surrounded by a metal layer, and wherein the non-electrically-conductive particle core comprises at least one of the

following: diamond, garnet, ceramic, oxides, silicides, silicates, carbides, carbonates, borides, boron fibers, and nitrides.

41. The RFID device of claim 26 or 40, wherein the at least one electrically  
5 conductive hard particle is attached to at least one of the first and second electrically  
conductive contacts by an electrolytic metal-particle co-deposition process.

42. The RFID device of claim 26 or 40, wherein the at least one electrically  
conductive hard particle is attached to at least one of the first and second electrically  
10 conductive contacts by an electroless metal-particle co-deposition process.

43. The RFID device of claim 40, wherein the metal layer comprises a nickel layer  
and wherein the non-electrically conductive particle core comprises diamond.

44. The RFID device of claim 40, wherein the metal layer comprises at least one  
15 of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum, palladium,  
lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium,  
rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of  
these metals.

45. The RFID device of claim 26, wherein the at least one electrically conductive  
20 hard particle comprises a plurality of electrically conductive hard particles.

46. The RFID device of claim 26, wherein the RFID device comprises a smart  
25 card.

47. The RFID device of claim 26, wherein the RFID device comprises a smart  
inlay.

48. The RFID device of claim 47, wherein the smart inlay comprises a component  
30 of at least one of a smart label and a smart paper.

49. A method for making a plurality of electrical components for RFID devices,  
each of the plurality of electrical components having a first electrically conductive contact,

each of the plurality of electrical components for physically and electrically connecting to an additional electrical component in an RFID device, the additional electrical component having a second electrically conductive contact that forms an electrical connection with the first electrically conductive contact, the method comprising:

- 5           providing the plurality of electrical components in an array;  
          attaching at least one electrically conductive hard particle to the first electrically  
conductive contact on each of the plurality of electrical components,  
          wherein the at least one electrically conductive hard particle has a hardness at  
least as great as that of at the second electrically conductive contact; and  
10          separating each of the plurality of electrical components from the array.

50.       The method of claim 49, wherein the array comprises at least one of a  
semiconductor wafer, a flexible circuit tape, a sheet comprising a plurality of chip carriers, a  
sheet comprising a plurality of chip modules, and a sheet comprising a plurality of antenna on  
15 a substrate.

51.       The method of claim 49, wherein the plurality of electrical components  
comprises at least one of the following: a plurality of chips, a plurality of chip carriers, a  
plurality of chip modules, and a plurality of conductive areas.  
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52.       The method of claim 51, wherein the plurality of chips further comprises at  
least one of the following: a plurality of discrete circuit devices, a plurality of integrated  
circuit devices, a plurality of memory devices, a plurality of microprocessor devices, a  
plurality of transceiver devices, and a plurality of electro-optic devices.  
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53.       The method of claim 51, wherein the plurality of electrically conductive areas  
comprises a plurality of conductive paths.

54.       The method of claim 51 or 53, wherein the plurality of electrically conductive  
30 areas comprises a plurality of antennae.

55.       The method of claim 51, wherein the plurality of electrically conductive areas  
comprise a conductive material comprising at least one of the following: copper, aluminum,  
gold, metal foils, conductive inks, conductive pastes, and graphite.



56. The method of claim 49, wherein the at least one electrically conductive hard particle is a metal particle comprising at least one of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum, palladium, lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium, rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of these metals.

57. The method of claim 49, wherein the at least one electrically conductive hard particle comprises a non-electrically-conductive particle core surrounded by a metal layer, and wherein the non-electrically-conductive particle core comprises at least one of the following: diamond, garnet, ceramic, oxides, silicides, silicates, carbides, carbonates, borides, boron fibers, and nitrides.

58. The method of claim 49 or 57, wherein the at least one electrically conductive hard particle is attached to the first electrically conductive contact by an electrolytic metal-particle co-deposition process.

59. The method of claim 47 or 57, wherein the at least one electrically conductive hard particle is attached to the first electrically conductive contact by an electroless metal-particle co-deposition process.

60. The method of claim 57, wherein the metal layer comprises a nickel layer and wherein the non-electrically conductive particle core comprises diamond.

61. The method of claim 57, wherein the metal layer comprises at least one of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum, palladium, lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium, rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of these metals.

62. The method of claim 49, wherein the at least one electrically conductive hard particle comprises a plurality of electrically conductive hard particles.

63. The method of claim 49, wherein the RFID device comprises a smart card.

64. The method of claim 49, wherein the RFID device comprises a smart inlay.

65. The method of claim 64, wherein the smart inlay comprises a component of at  
5 least one of a smart label and a smart paper.

66. An electrical component for use in an RFID device, the electrical component  
for physically and electrically connecting to an additional electrical component in the RFID  
device, the additional electrical component having a second electrically conductive contact  
10 that forms an electrical connection with the first electrically conductive contact, the electrical  
component comprising:

a component base, the component base further comprising

a first electrically conductive contact for forming an electrical connection with  
a second electrically conductive contact on the additional electrical component; and

15 at least one electrically conductive hard particle attached to the first electrically  
conductive contact,

wherein the at least one electrically conductive hard particle has a hardness at  
least as great as that of the second electrically conductive contact.

20 67. The electrical component of claim 66, wherein the electrical component is one  
of a plurality of particle-enhanced electrical components separated from an array comprising  
the plurality of particle-enhanced electrical components.

68. The electrical component of claim 67, wherein each of the plurality of  
25 particle-enhanced electrical components is identical.

69. The electrical component of claim 67, wherein the array comprises at least one  
of a semiconductor wafer, a flexible circuit tape, a sheet comprising a plurality of chip  
carriers, a sheet comprising a plurality of chip modules, and a sheet comprising a plurality of  
30 antenna on a substrate.

70. The electrical component of claim 66, wherein the electrical component  
comprises at least one of the following: a chip, a chip carrier, a chip module, and a  
conductive area.

71. The electrical component of claim 70, the chip further comprises at least one of the following: a discrete circuit device, an integrated circuit device, a memory device, a microprocessor device, a transceiver device, and an electro-optic device.

72. The electrical component of claim 70, wherein the electrically conductive area comprises a conductive path.

73. The electrical component of claim 70 or 72, wherein the electrically conductive area comprises an antenna.

74. The electrical component of claim 70, wherein the electrically conductive area comprises a conductive material comprising at least one of the following: copper, aluminum, gold, metal foils, conductive inks, conductive pastes, and graphite.

75. The electrical component of claim 66, wherein the at least one electrically conductive hard particle is a metal particle comprising at least one of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum, palladium, lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium, rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of these metals.

76. The electrical component of claim 66, wherein the at least one electrically conductive hard particle comprises a non-electrically-conductive particle core surrounded by a metal layer.

77. The electrical component of claim 76 wherein the non-electrically-conductive particle core comprises at least one of the following: diamond, garnet, ceramic, oxides, silicides, silicates, carbides, carbonates, borides, boron fibers, and nitrides.

78. The electrical component of claim 66 or 76, wherein the at least one electrically conductive hard particle is attached to the first electrically conductive contact by an electrolytic metal-particle co-deposition process.

79. The electrical component of claim 66 or 76, wherein the at least one electrically conductive hard particle is attached to the first electrically conductive contact by an electroless metal-particle co-deposition process.

5 80. The electrical component of claim 76, wherein the metal layer comprises a nickel layer and wherein the non-electrically conductive particle core comprises diamond.

81. The electrical component of claim 76, wherein the metal layer comprises at least one of the following: copper, aluminum, nickel, tin, bismuth, silver, gold, platinum,  
10 palladium, lithium, beryllium, boron, sodium, magnesium, potassium, calcium, gallium, germanium, rubidium, strontium, indium, antimony, cesium, and barium, and alloys and intermetallics of these metals.

82. The electrical component of claim 66, wherein the at least one electrically  
15 conductive hard particle comprises a plurality of electrically conductive hard particles.

83. The electrical component of claim 66, wherein the RFID device comprises a smart card.

20 84. The electrical component of claim 66, wherein the RFID device comprises a smart inlay.

85. The electrical component of claim 84, wherein the smart inlay comprises a component of at least one of a smart label and a smart paper.

25 86. A method for permanently physically and electrically attaching an electrical component having a first electrically conductive contact to an electrically conductive area on a substrate, the method comprising:

30 attaching at least one electrically conductive hard particle to at least one of the electrically conductive contact and a contact area of the electrically conductive area,  
wherein the at least one electrically conductive hard particle has a hardness at least as great as that of at least one of the electrically conductive contact and the contact area;  
placing a non-conductive adhesive between the electrically conductive contact and the contact area;

placing the electrically conductive contact in alignment with the contact area;  
applying pressure to hold the electrically conductive contact and the contact area  
together; and

curing the non-conductive adhesive,

thereby creating a permanent electrical connection between the electrically conductive  
contact and the contact area, and  
permanently physically attaching the electrical component to the electrically  
conductive area.

87. The method of claim 86, wherein the pressure applied is sufficient enough for  
the at least one electrically conductive hard particle to pierce a surface of at least one of the  
electrically conductive contact and the contact area.

88. The method of claim 86 further comprising applying pressure to the electrical  
component and the substrate during at least a portion of the step of curing.

89. The method of claim 86 further comprising depositing an electrically  
conductive metal layer on the at least one electrically conductive hard particle.

90. The method of claim 89, wherein the step of attaching the at least one  
electrically conductive hard particle and the step of depositing the electrically conductive  
metal layer occur simultaneously.

91. The method of claim 86, wherein the electrically conductive area comprises a  
conductive path.

92. The method of claim 86, wherein the electrically conductive area comprises an  
antenna.

93. The method of claim 86, wherein the electrically conductive area comprises a  
conductive material comprising at least one of the following: copper, aluminum, gold, metal  
foils, conductive inks, conductive pastes, and graphite.